

## V. CARTRIDGE FILTRATION

### A. Description of Unit

Cartridge filtration utilizes pleated or nonpleated disposable filter media. Its application is often limited to fluids containing no more than 0.01% solids (about 100 mg/L) and where cake handling is unnecessary. Each filter medium is usually associated with a particular pore size ranging from submicron up to 150 microns. The cartridges are cylindrical in configuration and bonded to plastic or metal hardware. Housings are available in plastic, lined metal or metal construction to meet various operating conditions of pressure, temperature and waste stream compatibility.

### B. Media

#### 1. Type of Media

The types of media used to manufacture cartridge filters include cotton, nylon, polypropylene, polyester, acetate, acrylic, glass, ceramics, metals, polyethylene, modacrylic, rayon, saran and fluorocarbons. In addition to the various types of filter media, filters are constructed of woven fabrics, felts, and nonwoven fibers, porous solids and polymeric membranes. Selection of the media and media construction is dependent on waste stream characteristics, filter operating conditions and desired effluent quality. Summarized below are some general information and uses for media material and construction type.

#### *Fabrics of Woven Fibers*

There are four basic type of weaves used as the base material for filters; plain/square weave, twill, chain weave, and satin. All the weaves can be made from textile fiber of natural or synthetic origin.

#### *Metal Fabrics or Screens*

Filters made of metals are available in a variety of weaves and types of metal which include nickel, copper, brass, bronze, aluminum, steel, stainless steel and other alloys. Good corrosion and high temperature resistance of properly selected metals make metal media desirable for long life applications, particularly since they can be cleaned.

#### *Pressed Felts and Cotton Battings*

Filtration with these materials usually occurs by deposition of the particles on and throughout the weave. They are often used to filter viscous materials such as gelatinous particles from paint.

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#### *Nonwoven Fabrics*

These filters are made of synthetic fibers like polyester and nylon, they are lighter than felts. They are used to filter highly viscous fluids to remove particles as small as 5 microns.

#### *Filter Papers*

Filter papers are available in a wide range of permeability, thickness and strength. They generally require perforation and a back-up plate for support.

#### *Rigid Porous Media*

These media are available in a wide range of materials including stainless steel, ceramics and some plastics. They are ideally suited for waste streams which require a wide range of chemical and temperature resistance.

Because some filters are composed of several media types it is important to make sure of the compatibility of each filter media with the particular waste stream. Table A-9 and A-b summarize the types of filter media and compatibility with generic waste streams. Table A-b gives a broader discussion on materials compatibility and is from recent vendor literature. While these tables are a generic guide on compatibility, corrosion handbooks, field experience and vendor literature should be reviewed to determine compatibility with specific known compounds and characteristics of the waste stream.

Table A-9 Characteristics of Filter Materials•

Generic Name	Abrasion Resistance	Resistance to acids	Resistance to alkalis	Resistance to oxidizing agents	Resistance to solvents	Maximum operating temperature, °C (°F) <sup>1</sup>
Acetate	G	F	P	G	G	98.9 (210)
Acrylic	G	G	F	G	E	148.9 (300)
Glass	P	E	P	E	E	315.6 (600)
Metallic	G					
Modacrylic	G	G	G	G	G	82.2 (180)
Nylon	E	F-P	G	F-P	G	107.2 (225)
Polyester	E-G	G	G-F	G	G	148.9 (300) <sup>2</sup>
Polyethylene	G	G	G	F	G	73.9 (165) <sup>3</sup>
Polypropylene	G	E	E	G	G	121.1 (250)
Rayon	G	P	F-P	F	G	98.9 (210)
Saran	G	G	G	F	G	71.1 (160)
Cotton	G	P	F	G	E-G	98.9 (210)
Fluorocarbon	F	E	E	E	G	287.8 (550) <sup>4</sup>

- Adapted from Mais, (1971). Symbols have the following meaning: E = excellent; G = good; F = fair; P = poor.
  1. °C = (°F - 32)/1.8; K = (°F + 459.7)/1.8
  2. Low-density polymer. Up to 230 degrees F, for high-density.
  3. Heat-set fabric; otherwise lower.
  4. Requires ventilation because of release of toxic gases above 400 degrees F.

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TABLE A-10 CHEMICAL RESISTANCE CHART

MATERIAL	RESISTANCE	MAX PERMISSIBLE TEMP. (Water) - Constant	MAX PERMISSIBLE TEMP. (Water) - Short-term
Polyvinyl Chloride (PVC, UPVC)	Resistance to most solutions of acids, alkalis, and salts and organic compounds miscible with water. Not resistant to aromatic and chlorinated hydrocarbons.	60C° 140F°	60C° 140F°
Chlorinated Polyvinyl Chloride (CPVC)	Can be used similarly to PVC but at increased temperatures	90C° 195F°	110C° 230F°
Polypropylene (PP)	Resistant to water solutions of acids, alkalis, and salts, as well as to a large number of organic solvents. Unsuitable for concentrated oxidizing acids.	60C° 140F°	80C° 175F°
Polyvinylidene (PVDF)	Resistant to acids, solutions of salts, aliphatic, aromatic, and chlorinated hydrocarbons, alcohols, and halogens. Conditionally suitable for ketones, esters, ethers, organic bases, and alkaline solutions.	90C° 195F°	110C° 130F°
Polytetrafluoroethylene (PTFE)	Resistant to all chemicals listed in vendor literature.	140C° 285F°	150C° 300F°

TABLE A-10 CHEMICAL RESISTANCE CHART

MATERIAL	RESISTANCE	MAX PERMISSIBLE TEMP. (Water) - Constant	MAX PERMISSIBLE TEMP. (Water) - Short-term
Nitrile Rubber (Buna-N)	Good resistance to oil and gasoline. Unsuitable for oxidizing agents.	90C° 195F°	120C° 250F°
Butyl Rubber Ethylene Propylene Rubber (EPDM, EPR)	Good resistance to ozone and weather. Especially suitable for aggressive chemicals. Unsuitable for oils and fats.	90C° 195F°	120C° 250F°
Chloroprene Rubber (Neoprene)	Chemical resistance very similar to that of PVC and between that of Nitrile and Butyl rubber.	80C° 175F°	110C° 230F°
Fluorine Rubber (Viton)	The best chemical resistance to solvents of all elastomers.	150C° 300F°	200C° 390F°

Adapted from vendor literature on fluid compatibility.

## 2. Configuration

Cartridge "clarifiers" are units which contain one or more replaceable filter elements. The housings are constructed of material which is compatible with the system operating pressure. Typical materials of construction include PVC and stainless steel.

Filter selection is based on the desired particulate effluent quality and compatibility with the waste stream to be treated. Where high effluent quality, low particle counts, i.e., number of particles remaining after filtration with a specified micron

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rating or removal of submicron particles is required, the filter pore size can be staged to minimize cost of the more expensive submicron particulate filters. Filter vendors have typically used a 3 or 4:1 ratio, of larger pore size filter changes to smaller pore size filter changes, as the most economical approach for staging. Most often, the method for selecting filter sizes for staging is determined in the field. Alternatively, filtration rates using multiple pore size membranes can be tested in the laboratory prior to field testing.

Cartridge filters come in 2 basic configurations. The first is a disposable tubular filter where filter elements fit into a cylindrical container or housing. These filters come in 2500, 5100, 7600, 10000 millimeter (100, 200, 300, 400 inch) lengths and can be stacked end-on-end within the filter housing to provide more surface area. For some installations as many as 300 filters can be installed per housing. See Figure A-16 for a cross section of a filter housing and filters. To determine how many filters may be required for a particular operation the designer must first know the system flowrate. Most filter elements have throughputs of 0.1 liters per minute/square meter to 1 liters per minute/square meter (0.25-4.0 gpm/ft<sup>2</sup>) and there is approximately 1 cubic meter of filtration area per meter length of filter (10 cubic feet per foot filter length). Therefore the number of filters required can be calculated using the following equation:

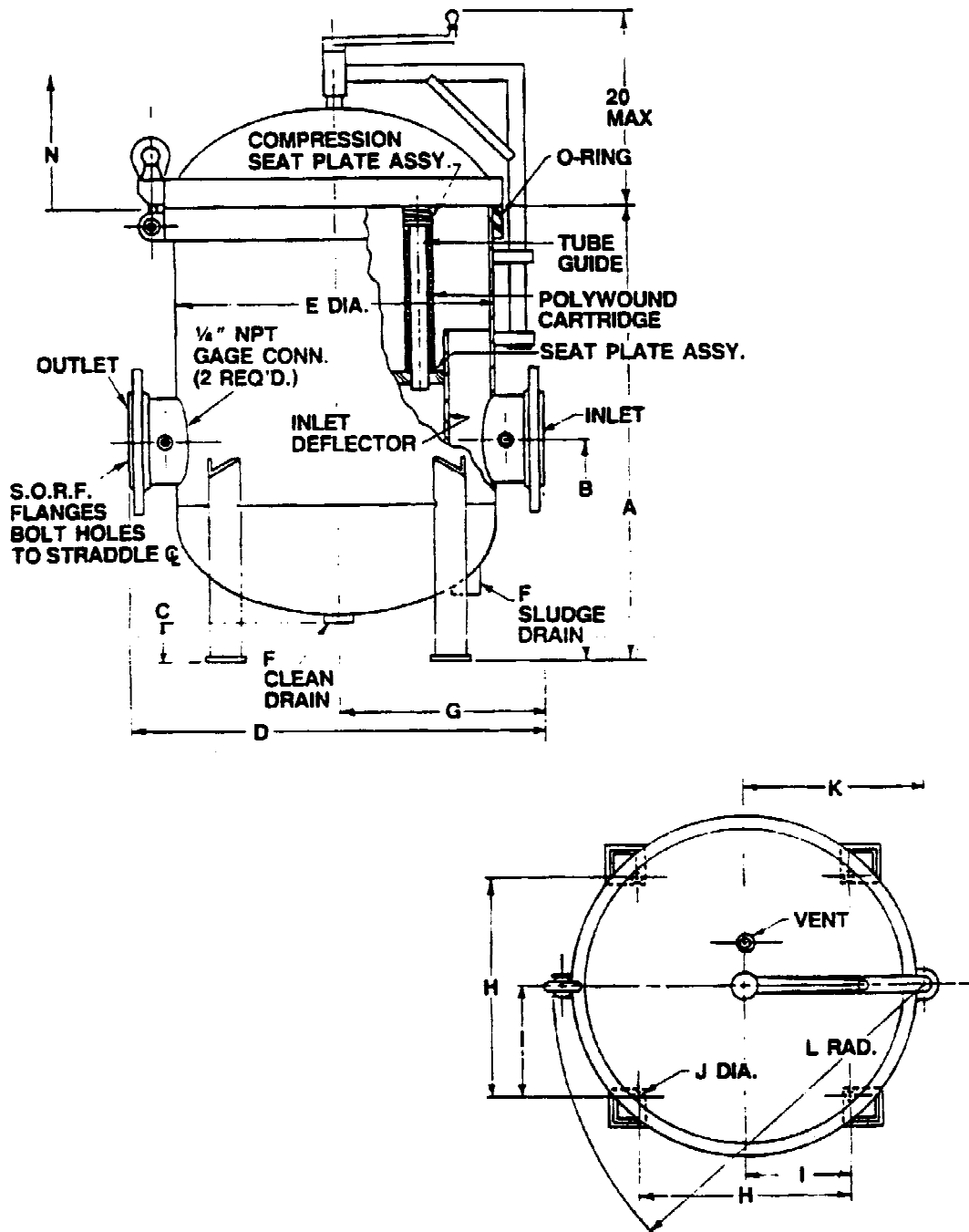
$$\frac{\text{system flowrate}}{\text{throughput} \times \text{surface area}}$$

The designer should always check vendor literature for the total available surface area for the selected cartridge filter.

The second type of cartridge filter is called a mechanical or edge filter where the cartridge consists of a stack of discs assembled so that fluids can flow between the discs but particles larger than the space between the discs are held at the outer edges. These filters are usually made of ceramic, metal or plastic so that the filter elements can be cleaned by backflushing, scraping or ultrasonic cleaning. In some cases the filters may be burned to remove deep seated particles or soaked in a cleaning solvent.

### 3. Media Support System

Filter housings are an integral part of cartridge filtration in that they need to be compatible with the system pressure and operating temperature, handle corrosive fluids, economically



**FIGURE A-16. CROSS SECTION OF CARTRIDGE FILTER HOUSING AND FILTERS**

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house the number of cartridges required, provide reliable seals to prevent fluid bypassing and account for easy replacement of filter elements.

To handle corrosive waste streams, housings can be constructed of a variety of steel and nickel alloys with multiple type liners available. Housings must meet pressure vessel codes and if temperature needs to be maintained to prevent solidification of some fluids a heated jacket for some filter housings is available.

Filter housings can house and operate in parallel up to as many as 300 filter elements. Systems that use multiple filter elements tend to have greater solids holding capacity per unit length of filter. This is due to a reduction in flowrate or flux across the filter with increasing filter area.

One of the most important features of filter housings is the sealing system which prevents bypassing of the filter. A common seal uses double open ended cartridges and a top compression ring on the housing. Piston type O-ring seals are most often used in single cartridge housings.

Cartridge elements have the designation DOE for double open ended seals and SOE for single open end designs. The most common sealing system in multi-cartridge units is the DOE design. The DOE design provides a knife-edge seal on the seat at the top of the filter cartridge. SOE cartridges are most frequently used in single cartridge housings where piston type O-ring seals are contained within the cartridges themselves. See Figure A-17 for a schematic of DOE and SOE sections.

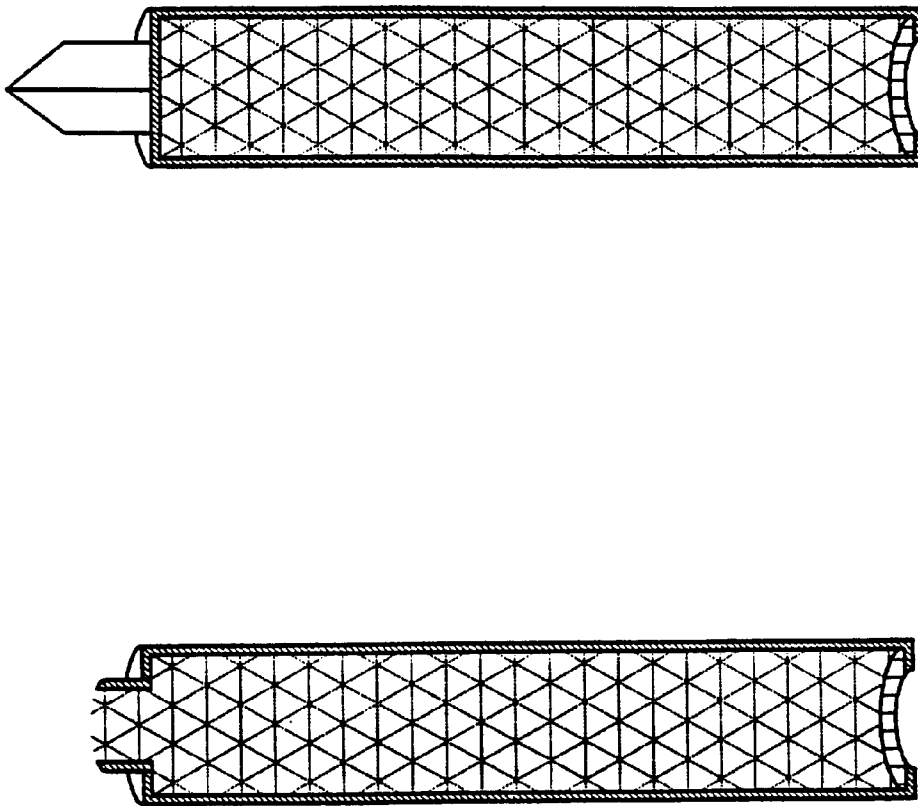
### C. Operating Conditions

Filters are changed when pressure differential across the system restricts the flow through the unit or effluent quality degrades due to cartridge filter deformation. Depending on effluent quality needs, filters may be staged according to pore size thereby minimizing cost for small pore size filters. System parameters which affect filter selection include temperature, pressure, fluid compatibility, efficiency, fluid viscosity, type and quantity of contaminant, maximum allowable pressure drop across filter assembly, required throughput and flow rate.

#### *Temperature*

Glass, ceramic and metal filters are the most commonly used filters where continuous operating temperatures exceed 260°C (500°F). In the temperature range of 150-260 °C (302-500 °F)





DOUBLE OPEN ENDED  
CARTRIDGE FILTER

SINGLE OPEN ENDED  
CARTRIDGE FILTER

**FIGURE A-17. DOE, SOE CARTRIDGE FILTER CROSS SECTIONS**

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fluorocarbon filters as well as glass, ceramic and metal filters are often used. From 80-260 °C (176-500 °F) almost all other media types can be used provided metal hardware is used. Below 80°C (180°F) all filter medias can be used with either plastic or metal hardware. Refer to Table A-9 for maximum operating temperature for each filter material.

#### *Pressure*

System pressure is needed to maintain flow as the cartridge accumulates particles. In determining operating pressures the designer must also consider the pressure necessary for other resistances such as pipe elbows and valves. Excessively high pressure can cause structural damage to the filter. It is therefore important to know the filter minimum pressure to maintain flow and evenly distribute solids across the filter as well as maximum operating pressure which can cause filter damage. As the filter plugs high differential pressures across the filter are realized, causing particle or pore deformation. Some vendors can provide systems with differential pressure alarms to warn of impending filter failure.

#### *Fluid Compatibility*

As previously discussed in section A, filter compatibility with the waste stream must be determined from available literature and from experience. In addition to the literature review a chemical compatibility test can be performed by immersing the cartridge filter in the fluid for at least 48 hours. At the end of the selected soak period observe the filter for changes in color, structural integrity, swelling, softening, deformation and any other changes in the filter's and the filter hardware's physical appearance. Also observe changes in the fluid including changes in color, clarity and viscosity.

#### *Filter Efficiency*

Suppliers of cartridge filters use different test methods for rating a filter's performance. In most cases these test methods cannot be correlated. Filter ratings include nominal filtration rating, absolute filtration rating, beta ratio and filtration ratio. Nominal filtration rating represents some percentage of removal of particles of a given size or larger. It is not typically reproducible from cartridge to cartridge. Absolute filtration rating is the diameter of the largest spherical particle that will pass through the filter under specified test conditions by the vendor and are sometimes performed in air environments. Beta ratio is the total number of particles in an influent waste stream greater than a specified size divided by the number of particles in the treated effluent waste stream of the same size. Filtration ratio is the number of particles in the influent equal

to some specified size divided by the number of particles in the effluent equal to the same specified size. Most cartridge filter with absolute ratings of 75 will typically have a filter removal efficiency rating of 95%.

#### *Fluid viscosity*

Filter type, area and pretreatment needs are all influenced by pressure drops resulting from fluid viscosity. Nickolaus suggests that for coarse filtration and high viscosities above 3000 centipoise (cP) (7230 lb/hr•ft) metal mesh cartridges are recommended because of their high permeability and strength. He also indicates that nonpleated cartridges have been used at viscosities of 20,000 cP (48,400 lb/hr•ft) but at low flux rates of <0.2 liters per second per cartridge (0.3 gpm). To reduce pressure drops caused by fluid viscosity, filter area can be increased.

#### *Type and Quantity of Contaminant*

The type and physical characteristic of the contaminant influences filter type and area. Hard, irregular/inert type particles are more easily filtered with cartridge filters than are gelatinous materials. Contaminants of an organic nature influence cartridge selection depending on relative concentrations. At low levels the cartridges may fail on differential pressure before the solvent breaks down the structural integrity of the filter. At higher organic loadings, the structural integrity may be impaired prior to failure due to solids loading and pressure drop. Excessive pressure and flowrate may cause the pores of the filter to become misshapen and widen, resulting in poor effluent quality.

#### *Maximum Allowable Cartridge Pressure Drop*

This is a parameter often specified by the manufacturer and represents the maximum operating pressure at which the filter will fail structurally. Often overlooked pressure drops are those associated with housing/system hardware which should be considered when selecting a filter for available pressure drop. Filter selection should minimize the ratio of hardware losses to total available pressure drop.

#### *Required Throughput and Flow Rate*

Throughput per cartridge is best determined by laboratory tests which are relatively easy to perform. It is important the test fluid is representative of the waste stream to be treated. From pilot/bench scale tests, throughput per cartridge can be determined and surface area needed for filtration to maintain pressure drop across the cartridges can be optimized without impacting the structural integrity of the filters. Depending on the waste stream to be treated throughput per cartridge can range

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from 0.1 liters per minute/square meter to 1.0 L/(min m<sup>2</sup>) (0.25-4.0 gpm/ft<sup>2</sup>). The actual throughput is impacted by fluid viscosity and filter media pore size. Generally all of the factors above impact filter throughput and they must all be considered when sizing the system.

#### D. Advantages/Disadvantages

Cartridge filters are flexible in that different ratings and materials of construction can be interchanged to accommodate changing conditions in waste streams. Multiple cartridges housings are available to supply the surface area needed to meet desired throughput and flow rate while minimizing pressure drop. Multi cartridge housings also have the advantage of requiring little space. Most multi cartridge housings are typically 3000-6000 millimeters (10-20 feet) in diameter and can be 2500-10,000 millimeters (8-30 feet) high depending on the number of cartridges stacked within a single unit.

Cartridge filtration can be used for any flowrate simply by adding more filters. Some applications have flowrates of 4 million liters per day to 8 million liters per day (1-2 mgd) such as in the semiconductor industry. In this application the wet stream undergoes rigorous pretreatment to minimize changing of filter elements. For HTRW applications cartridge filter can be used to remove pinpoint flocs not readily removable by media filters. As discharge limitations become more stringent cartridge filtration will have a larger role at HTRW sites.

The biggest limitation for cartridge filters is the inability to treat waste streams with solids loadings greater than 0.01 percent solids. For this reason cartridge filters are often used as a polishing step or to protect a downstream treatment unit subject to biological or particulate attack.

Cartridge filters are limited in use on hazardous waste sites in that the cartridge housing needs to be opened to replace filter elements. This creates health and safety exposure concerns. When used in treating hazardous waste, the costs for disposal of a single cartridge is significant when compared to the total quantity of contaminant removed. Solids removed by other systems which can be backwashed have the advantage of being able to remove the solids from the filter bed by backwashing. Therefore there is no need to change the media as with cartridge filtration resulting in significant cost savings. However, it should be noted that capital costs for cartridge filter systems

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is typically less than other types of filtration systems, e.g,  
pressure or gravity.

E. Reference. See Appendix D.